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A new Straight Line Matching Technique by Integration of Vision-based image processing

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Abstract

In this paper, a new algorithm for a new straight line matching by integration of vision based image processing is being proposed. The corner detector and Hough Line Transform were employed respectively the feature extraction of corners and edges from the left and right images. After process of corner detection has been already extracted the corner points in the left and right images, each corner use the computation of a cross-correlation which is based on matching score for putative corner correspondences. This algorithm uses the corner pairs from reference points of started-end corner. The matching comparison between corner pairs and Hough Line are able to generate a new straight on the edge of both left and right images. From corner correspondences in the image pairs are going to compare with a new straight line to get the result of new straight line correspondences. This method is simple and easy to apply to the 3D recognition of geometric shapes and is able to reduce the number of false matches in a probabilistic manner which the result arise from incomplete Hough Lines. The results have shown the new straight line correspondences that are effective, complete and could be used in a 3D recognition process.

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Keywords: Straight line matching; normalized-cross-correlation(NCC); image processing

1. Introduction

Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images. In general, high-dimensional data from the real world are utilize in order to produce numerical or symbolic information, e.g. in the forms of decisions. A theme in the development of this field has been to duplicate the abilities of human vision by electronically perceiving and understanding of an image. The application of computer vision techniques are employed among the industries, medical field, robotic technologies and etc. In various industries, Computer Numerical Control (CNC) machine is important in manufacturing process. CNC machine must operate at a fast pace, with accuracy and minimum error. Therefore, the computer vision is the key role of the machine tools that can work in intelligent system and prevent the errors which occurs with machine tools to quicken and increase accuracy. This system uses the images to analysis process by using the basic of image processing technique for detection the feature of the 2D-image. The 2D feature extraction module extracts the feature of the object. Types of images features include edges, corners, and interest points. These features are processed to help in segmentation and object recognition. Edge detection is an area that is very important in the field of computer vision [1]. One of the powerful global methods for detection edges (lines, circles) is called the Hough Line Transform. The advantage of Hough Transform is that pixels lying on one line does not need for all the pixels to be contiguous. The correct detection of lines and circles strongly depends on fine image preparation [2]. On the other hand, Harris corner detection is a decent method which yields high quality features. The Harris corner detection is a popular interest point detector due to its strong invariance to rotation, scale, illumination variation and, image noise. The feature-

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based matching is the process in which two representatives (lines, corners) of the same object were paired together. The matching is a basically the selection process in which features were paired according to some measures of similarity. Points and lines are two commonly use features in stereo matching process [3]. Extraction and selection of these feasible matching candidates from the enormous amount of points become a critical problem, matching with massive features suffers from a burden of computation and memory space. Thus, feature extraction and selection process determine whether a proficient matching result have derived. Contrary to using points, using lines as matching features relieves the burden of matching with massive amount of features. The feature selection process is able to simplify the complexity of computation and memory space reduction.

Several line matching algorithms have been introduced in the previous and current researches. These algorithms are typically divided into two types; either matching individual line segments or matching groups of line segments [4]. Sang Ho Park et al., [5] proposed a new eigenvector-based line feature matching algorithm. This approach resolves an inherent problem in relation to the order and correspondence in the eigenvector approach. The results exhibited that the proposed algorithm performs matching of the line features in a fast, robust and efficient way. However, in the case where a certain some line features in a label image were broken, the proposed algorithm may not work properly in the presence of severely broken lines. A.O.OK et al., [7] have studied a new methodology for the reconstruction of line features from multispectral stereo aerial images. This method adopted the principal component analysis technique which was developed to extract the straight edge segments. The selection of line pairs using proximity of the minimum 2D Euclidean distance between two lines, the angle enclose by line segment and similarity of flanking region. The final pair matches after a weight pair-wise matching similarity score which were computed over a total of eight measures. However, the pair-wise matching does not always guarantee one to one matches for each line. The quality of images and noise level involved has probably affected the quality of the extracted line. Annarmaria et al., [8] corner detection algorithm can be developed by combining it with fuzzy reasoning. A similar measure that can decide which feature points are the best candidate for being the corresponding points. And Zhang et al.,[9] a 2D edge feature detection algorithm will extract the edges of the object of interest by using background subtraction technique. Therefore, using the virtual image as a background image and then, the real image as the foreground image. 2D extraction feature use corner detection. Subsequently, a hypothesis have been made that an edge exits between every two corners. Moreover, there have been proposal to solve correspondence for two edges by using the absolute evaluation functions. These functions are presented as the Epipolar evaluation function, the length evaluation function and, the absolute orientation evaluation function. However, the edge is only about half as long as the actual length, the algorithm considers that it does not correspond to the edge pairs.

The past researches have improved 2D extraction feature to reduce the difficulties form noise environment before it go on to matching process. The matching algorithm has varieties of methods that have evolved and obtain more accurate results. That is an advantage of processing the 3D object recognition. Although, there are some disadvantages in computing complex data and some results are mismatched which caused by noises environment that the feature detection have failed, and then it further affects the matching process in the final step. This research sought to find a simpler method for implementing a geometric shape. The goal is matching a new straight line between the left and right images. Line matching is often used in the first step within the 3D-scene reconstruction. The new algorithm presents the integration between Hough line transform and Harris corner detection which then, they are going to generate a new straight line. While Harris corner was running a matching process between left and right images using Normalized Cross-correlation(NCC) that obtain corner pairs that were inputted to compare with a new straight line and result in the new straight lines correspondence between two images. The new algorithm illustrates a new straight line correspondences to its correct matches and it will be put to use in the 3D recognition process. The remainder of this paper is organized as follow: Section 2) system overview, Section 3) Matching algorithm, Section 4) experiment results and Section 5) conclusion.

2. System Overview

The new algorithm of a new straight line matching technique presented in Fig. 1.

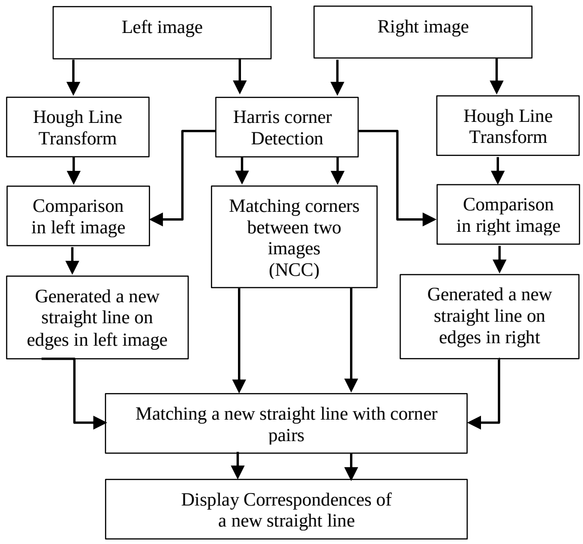

Fig.1. Process of a new straight line matching technique

Two images were acquired by two cameras capturing mode. The captured left and right images were processed by the 2D feature extraction mode to extract the 2D edge data of the object. The 2D feature extraction that was chosen for the extraction of object by using Hough line transform and Harris corner detection. Hough line are automatically extracted with Canny-operator [10] and improved Hough Transformation that presented by Costa [11]. The method firstly use Canny-operator to detect edge points in the imagery, and then obtain parameters (ρ, θ) of straight lines by Hough Transformation. Following that, all feature points whose distance with the straight line satisfies $\Delta\rho < \mathrm{T}$ are projected to x-axis and y-axis. Finally, the endpoints and length of lines segment (Hough lines) are obtained by detection the continuity of these projected points [6]. The corner detection aims at accurate extraction of the corners of the images, both for the object of interest and other objects. All the detected corners are stored in the set $c = \{(x_i, y_i)\}$, where (x_i, y_i) are the corner location on the image [12]. These corners in the left and right images were input into matching corners by using normalized-cross-correlation (NCC). It compared the gray levels in a window around a corner point with the gray levels around the corresponding pixels in the other image. The feature point matching based on NCC is well employed because of its excellent anti-noise ability and, thus is of importance in the image matching. At the same time, corners in each image will be paired by the Cartesian product. Then, the started-end point of corner pairs are defined and constructed the suppose lines between two corners in the object are being constructed. Afterward, the suppose lines will be matched with Hough lines to a hypothesis state that a new straight line exists between every two corners. The comparison of a new straight line with corner pairs from NCC find out the best match in the correspondence module and then will be displayed together with new straight lines correspondences.

3. Matching Algorithm

3.1. Normalized cross-correlation method

The 2D feature extraction of the corner points using Harris's equation or the smallest eigenvalue on two images (left and right). The goal of matching process is to find a match between the pixels in the left and right images. More importantly, the goal is to establish correspondences between the interest points in the two images. Comparison of the gray levels in a window around a corner point with the gray levels around the corresponding pixel in the other image. The normalized cross-correlation (NCC) which is one of area-based the matching typical metric was employed. Matching using NCC is defined as

$$NCC(u,v) = \frac{\sum_{x,y}\left[f(x,y) - \overline{f_{u,v}}\right]\left[t(x-u, y-v) - \bar{t}\right]}{\sqrt{\sum_{x,y}\left[f(x,y) - \overline{f_{u,v}}\right]^2 \sum_{x,y}\left[t(x-u, y-v) - \bar{t}\right]^2}} \quad (1)$$

where $t(x, y)$ is the pixel value of the template image and $f(x, y)$ is the pixel value of the input image. $\overline{f_{v,u}}$ and $\bar{t}$ are the averages of the pixel values within a window in the left and right image respectively.

NCC is computed between every pair of corresponding corner pixels. The NCC ranges between -1 and 1, if the value of the NCC approaches 1 then, two interest points has similar feature descriptors. A matched point and its two closest neighbours in the left are used to construct a polygon model. Let the point $f(x, y)$ from the left image can be taken as the center for the choice of the neighbourhood window of N×N. The correlation calculated between this window and the neighboring windows with the same size of all the point $t(x, y)$ in the right image. The feature point with the greatest correlation coefficient and greater than the given threshold, is taken as the matching point. A polygon model is constructed with three points $f_i(x_i, y_i)$, *i* = 1, 2 and 3 in the left image and the corresponding one is constructed with $t_j(x_j, y_j)$, *j* = 1, 2 and 3 in the right image. The polygon model constructed in the left is kept fixated. The matching point for every one of the point in the right image is sufficiently close, and then the two polygons are valid match. It is illustrated in Fig.2. Point $t(x_1, y_1)$ and $t(x_3, y_3)$ in the right image have difference of misalignment to right compared to $f(x_1, y_1)$ and $f(x_3, y_3)$ in the model from the left image in Fig. 2(c). In order for points to establish one to one interest point correspondence, two interest points will be accepted as a match and can be used in the next process.

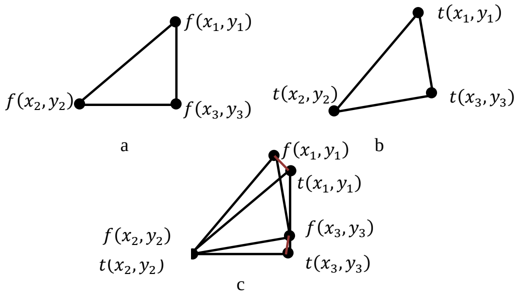

Fig. 2. Polygon constructed by three points; (a) the points in the left image; (b) the points in the right image and (c) corresponding points between two polygons

3.2. Identification on corner pairs

The interest points on the left and right image are detected by Harris corner detection that identifies numbers both images in each corner. Preceding that, each corner will be paired crossing by using the Cartesian product of *A* and *B* within the left and right, denoted by $A \times B$, is the set

$$A \times B = \{(a,b) | a \in A \, and \, b \in B\} \quad (2)$$

where, *a* = Start corner points in set A(left & right image)
b= End corner points in set B (left & right image)

In each ordered pairs, the first component is an element of *A* and, the second component is an element of *B* in the left and right image. Prior to the corner pairs being input into the comparison process within image that will later construct the suppose lines in between two corners in the left and right images, in order to prevent confusion during comparison process. Hence, the straight line generated from between corner pairs called " the suppose line".

3.3. Comparison Process

The overall algorithm generates a new straight line is illustrated in Fig.3, a new straight line was generated, starting at the feature detection by using Hough line transform and Harris corner detection. Hough line transform extracted the edges on image that are obtained through the Hough lines may be skewed, broken and, etc. The Fig.4 have shown Hough line are closely, overlapping of Hough lines are presented only by one single suppose line between two corners. The suppose lines generated from started-end point of corner pairs as shown in Fig.4 (a). All the Hough lines and the suppose lines was sorted by identification of numbers in each line for both Hough line and suppose lines. After that, calculating the Gaps neighbouring (Gn_s, Gn_e) are the distance between Hough line and the suppose line as shown the sample in Fig.4 (b), with the assumption that all lines and all corners from the left border and end the right border. The *x-y* coordinate (Hough Line; *HLi*, Suppose Line; *SLi*) of the left and right started-end points was used to represent line *i*. The Gaps during neighbouring *HLi* and *SLi* are exhibited in Fig.4(b). In the observation, the parallel line is a similar the area of parallelogram formed by vector, so the neighbouring gaps were able to be calculated (*Gn*) by Cross product.

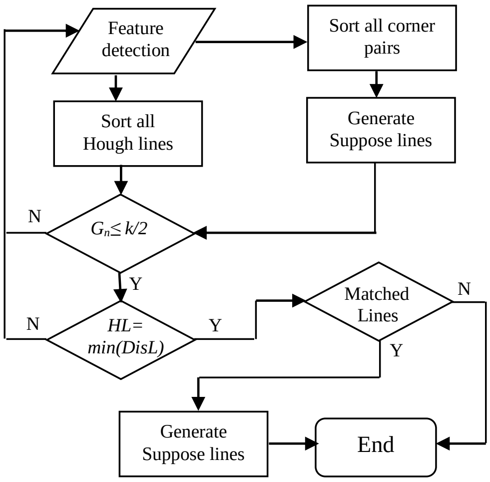

Fig. 3. Flow chart of a new straight line generates

Fig.4 (b) illustrate the suppose line as reference line, the candidate line (Hough line) is compared with the suppose line in order to compute the distance of Gaps neighbouring (Gn_s, Gn_e). The distance *Gn* at started and end points of Hough lines. For all candidate pairs model, the comparison of individual stared-end point and tested the proximity of the points to the suppose lines was made by computing their orthogonal distance, due to the goal of this part which that, the Hough lines that have short distance *Gn* or the Hough line and suppose line lying on the same edge or not. The proximity measure will be computed from started and end point are orthogonal to the suppose line in search for the Hough lines are in nearest region with the suppose line as the samples are HL_3, HL_4, and HL_5 in Fig.5.

Although, either the stared or end point of Hough line that will be significantly short distance to the suppose line but it could not show those Hough lines are the nearest or lying on the suppose line is also shown in Fig. 5.

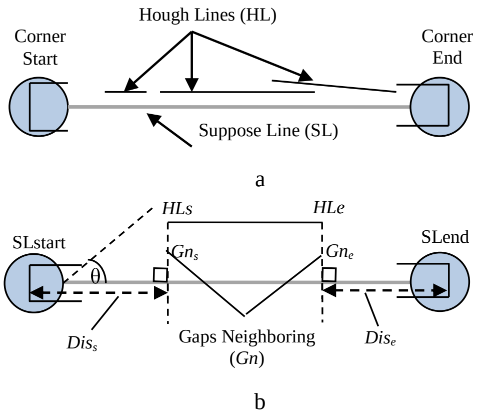

Fig.4. Shown the Hough lines and Suppose lines; (a) problems of Hough lines; (b) the definition of the gaps neighbouring (*Gn*) and distance between two started points(Dis_s) and distance between two end points(Dis_e)

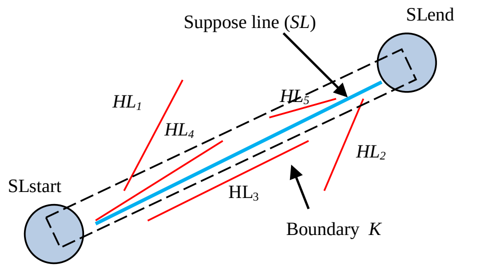

Fig. 5.Identify candidate pair-wise lines and the proximity measure

3.3.1. Pair-wise lines matching and generation a new straight line

In the feature extraction section, the Hough lines and the corners on images was obtained until it was able to matched corner pairs and finally to assumed the construction of the suppose lines. In the next step, Gaps neighbouring (*Gn*) was computed and inputted to this section which will be filtering the Hough line by using Gn_s and Gn_e on started-end points are a filtered by condition as below

$$SL(start, end) = \begin{cases} 1 & if\ \left|Gn\left(start, end\right)\right| \leq k/2 \\ 0 & otherwise \end{cases} \quad (3)$$

where, *Gn(start,end)* are the Gaps neighbouring of Hough line(*HL*) and Suppose line(*SL*), *HL(start, end)* is the Correspondence Point on start-end point of *SL(start, end)* also, and *K* is a constant.

As mentioned above, the issue of Hough lines occurred from noise environment in Hough transform process was noted, and that is when obtaining the Hough lines from extraction the edges of object are shown in the results as overlap, broken or may be due to feature extraction which area is not needed. Sample in Fig.5, shows that Hough lines are not as complete as HL_1, HL_2, HL_3, HL_4 and HL_5 respectively. These Hough lines are candidate lines to be used in comparison with suppose line. This process defined the boundary K for filtering the straight lines that have Gn of started-end points with the least value and within the constant of the boundary K as identified by dashed line in Fig.5. This method can reduce the number of candidate lines in the following examples HL_3, HL_4 and HL_5 are started-end points under the conditions of Gn and boundary K but HL_1 and HL_2 are started-end points not under the conditions that must be moved to candidate lines are inputted into comparison in the next suppose line. In one side of the benefit of determining the boundary K that can reduce the numbers of the suppose lines as well. As the suppose lines are computed by the Cartesian product from two sets of corner that have some of the suppose lines existed from two corners which does not have the real edges on the object. Thus, within the area boundary K of the suppose lines that no candidate line (Hough line) insert into make a comparison will be affected eliminate them automatically.

To create a new straight line from obtaining the results from a comparison between the Suppose line and the Hough line to generate a new straight line is the result which will be presented that the Hough line have the proximity or in between the started and end point of the suppose line or corner pairs. As mentioned in the introductory section, the generating of a new straight line used the reference of the started and end point of the corner pairs. From the Fig. 5 shown that there are three Hough lines under the condition in the previous section. The construction of a new straight line may be overlap with three new straight lines in between the same one corner pairs. Therefore the resolution of this problem is an addition the filtering process for screened lines from three Hough lines to only one line that has the most similarity with the suppose line in order to generate to a new straight line from only one Hough line and only one corner pairs under the condition as below.

$$DisL = Dis_s + Dis_e \tag{4}$$

then,

$$HL = min(DisL_1, DisL_2, DisL_3, \ldots DisL_n) \tag{5}$$

where, n = the numbers of Hough line

Dis_s = distance between HL_s and SL_s
$Dise$ = distance between HL_e and SL_e
$DisL$ = summation of Dis_s and Dis_e

These steps to fine method are used to estimate the correspondence points. In the estimation, the correspondence points which have the closely degree angle, and start-end points was obtained.

A similar measurement for all parameters is defined as the value of the minimum of the parameter values for the match starts points and end points. The Hough line (HL) and the suppose line (SL) met the condition of fine match, and obtained a new start-end point is the corner pairs that correspondence with the HL. Hence, a new straight line on the edge of the object are able to be generate. The generation technique of a new straight line that is defined the start and end point, as well as, by using the reference of the start and end point of corner pairs. So, the start and end point of a new straight line is the same point of corner matching of the left and right images. Finally, a new straight line matching can be defined as presented in Section 4, the experiment results.

4. Experiment Results

The proposed method is implemented in OpenCv 2.3.1 C++ language on a Personal Computer with Intel(R) Core™ is-2520 CPU. Both synthetic and real images are used in the experiments and verified with the following.

4.1. Synthetic images experiment

To verify the effectiveness of this algorithm, a set of synthetic images are firstly selected. The resolution of the synthetic image is 400×330. The results are shown in the Fig.6a and b, a new straight line of synthetic images. There are 6 new straight lines are generated on the edges and detected 5 corners of the object in the left and right images.

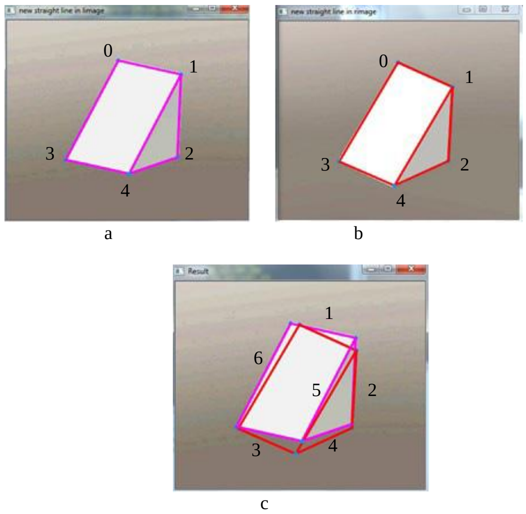

Fig. 6. A new straight line on edge for synthetic images; (a) new straight lines in the left image; (b) new straight lines in the right image and (c) the new straight lines matching

The new straight lines matching result shown in Fig. 6(c), where the same serial number in the result image means a line matched pairs. There are 6 new straight lines that have been matched in total, the match yields 100% accuracy for the synthetic images and without noise interference.

4.2. Real images experiment

In this experiment, the images on the real object was taken to test the performance of the matching algorithm. The resolution of the synthetic image is 500×500. As shown in Fig. 7(a) and (b), there are 65 Hough lines in the left image and 69 Hough lines in the right image respectively.

The Fig. 7(c)and (d) were the illustration of the result of Harris corner detection, there are 7 corners detected in the left and right images. The corners are the reference points that are started and end points for the construction of the Suppose lines between two corners. The Hough lines detected on edges in the left and right images by Hough transform as shown in Fig.7(a) and (b), which detected the background and noise on surface of object as well. After that, new straight lines on edges in the left and right images was obtained and matched by using the new algorithm, the new straight lines matching result were exhibited in Fig. 8.

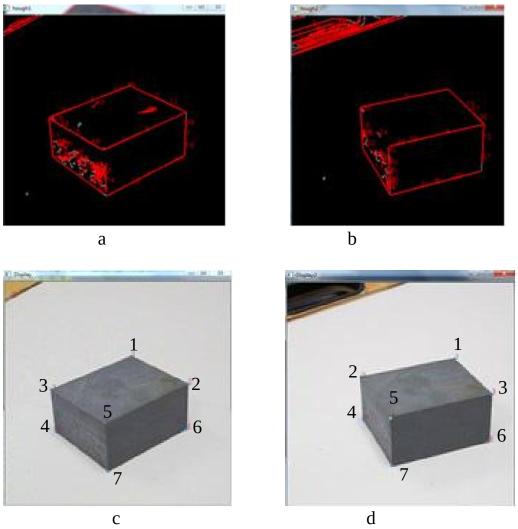

Fig. 7. the feature extraction on real images; (a) and (b) Hough lines detected edges on real images; (c) and (d) corner detected on real images.

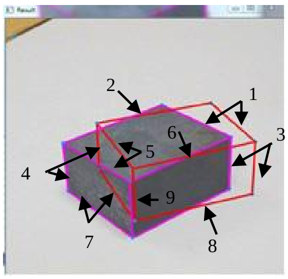

Fig. 8. A new straight line matching for real image

Total of 8 new straight lines are targeted for matching, and the result is correct, matching 8 new straight lines pairs, the matching ratio accuracy is 100%.

5. Discussion and conclusion

The new straight line matching technique is being proposed in this paper. This algorithm uses the basis of image processing technique to apply with NCC. The selection of Hough Transform for detection of edges and Harris corner detection is detected the corners was made, which both methods are popular in the research field. Although, the detection Hough lines on edges showed the results not completely as it was broken and overlap. However, the integration of Hough transform and Harris corner detection by comparing them to construct a new straight line on the edge illustrates excellent results and finally the new straight lines matching between two images by determine of the started and end points of corner pairs from image pairs which used NCC. The results of new straight lines matching were met the goal in efficiency and completeness.

For the experiments of the synthetic images and real images of a simple geometric shape, due to the new straight lines detected, results were satisfying and all of the robust and efficient new straight lines matching. The advantage of this algorithm is that in can be used to reduce the candidate lines matching on surface of the object and background which have benefits to the process of a new straight line matching between the left and right images. However, the disadvantage of matching by NCC that it was matched incorrectly because image pairs are situated in more difference angles.

In order to improve the performance of the proposed the new straight line matching technique, further research will be conducted in order to improve the difference angle of the image pairs and to focus on the complexity of real images.

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